Field Growth in the Super Giant Wattenberg Field, Denver Basin, Colorado*

Steve Sonnenberg¹

Search and Discovery Article #20468 (2019)**
Posted December 11, 2019

**Datapages © 2019 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/20468Sonnenberg2019

¹Colorado School of Mines, Golden, Colorado (ssonnenb@mines.edu)

Abstract

The giant Wattenberg Field area of Colorado was discovered in 1970 by Amoco Production Company and Vessels Oil and Gas with completions in the Lower Cretaceous Muddy (J) Sandstone. Wattenberg straddles the Denver Basin synclinal axis and is regarded as a basin-center stratigraphic petroleum accumulation. Additional production was encountered in five other formations during the development of the field (Plainview, Codell Sandstone, Niobrara Formation, Terry and Hygiene sandstone members of the Pierre Shale). The Terry and Hygiene were first produced in 1972; the Codell in 1981; the Niobrara in 1985; and the Plainview in 1998. Reservoir quality in the various horizons is generally poor which mandates hydraulic fracture stimulation for production. The greater Wattenberg area (GWA) covers approximately 2600 square miles. Production occurs from approximately 4000 to 8500 feet across the field. Cumulative production from the field is 812 MMBO and 7.5 TCFG from over 35,000 wells.

The field is currently at peak production due to recent horizontal drilling activity in the Codell and Niobrara. Original reserves were estimated to be 1.1 TCFG for the J Sandstone. The addition of multiple productive horizons in the field area has significantly added to the total reserve number. The field is ranked by the EIA based on reserves as the fourth largest oil field and the ninth largest gas field in the US. Source beds for oil and gas in Wattenberg are the Skull Creek Shale, Graneros Shale, Greenhorn Limestone, Carlile Formation, Niobrara Formation, and Sharon Springs Member of the Pierre Shale. The Wattenberg area is a “hot spot” or positive temperature anomaly. This is an important reason the area is so prolific. Temperature gradients range from 16-18° F/1000 feet on the edges of the field to about 28-29° F/1000 feet in high GOR areas. The temperature anomaly is related to where the Colorado Mineral Belt intersects the Denver Basin. The mineral belt is a northeast trending zone across Colorado, of Late Cretaceous to Early Tertiary mineralization. The mineralization is associated with high geothermal gradients and hot fluids.

Selected References

Field Growth in the Super Giant Wattenberg Field, Denver Basin, Colorado

Dr. Steve Sonnenberg
Colorado School of Mines
Wattenberg Field
EIA top 10 Oil and Gas Field

Top 10 Oil Fields
1. Eagleville (TX) – 238 million barrels
2. Spraberry (TX) – 99 million barrels
3. Prudhoe Bay (AK) – 79 million barrels
4. Wattenberg (CO) – 47 million barrels
5. Briscoe Ranch (TX) – 62 million barrels
6. Kuparuk River (AK) – 29 million barrels
7. Mississippi Canyon (Fed Gulf) – 15 million barrels
8. Wasson (TX) – 19 million barrels
9. Belridge South (CA) – 23 million barrels
10. Green Canyon (Fed Gulf) – 27 million barrels

Top 10 Natural Gas Fields
1. Marcellus Shale (PA & WV) – 2,836 billion cubic feet
2. Newark East (TX) – 1,951 billion cubic feet
3. B-43 Area (AR) – 1,025 billion cubic feet
4. San Juan Basin (CO & NM) – 1,024 billion cubic feet
5. Haynesville Shale (LA) – 1,425 billion cubic feet
6. Pinedale (WY) – 568 billion cubic feet
7. Carthage (TX) – 653 billion cubic feet
8. Jonah (WY) – 239 billion cubic feet
9. Wattenberg (CO) – 304 billion cubic feet
10. Prudhoe Bay (AK) – 147 billion cubic feet
Productive Areas-GWA

Wright, 2005; Modified after Ladd, 2001
Wattenberg Field Production

(\sim 40,000\) wells

- **JSS Discovery**
- **Terry/Hygiene Discovery**
- **Codell Discovery**
- **Niobrara targeted**
- **Rule 318A 1998**
- **Rule 318A modified 2005**
- **Horizontal Drilling**
- **Amoco sells Wattenberg interests 1997**
- **Amoco Farm Out of Codell to HS Resources and Snyder (1991, 4 yr boom)**

**Cum Prod:**
- 884 MMBO
- 8.1 TCFG
- 263 MMBW

**Production Data:**
- **BOPD**
- **MCFGPD**
- **BWPD**

**Timeline:**
- 1970
- 1980
- 1990
- 2000
- 2010
- 2020
A Near Miss!

- All DSTs or cores taken in the J indicated shows of gas
- Core analyses of the J compared with those of the Dakota in the SJB
- Old wells in area remarkably similar
- Earlier discovery at Roundup - 1967
- Wattenberg discovered - 1970

Original Est. EUR 1.1 TCF

Matuszczak, 1973
GWA Spacing History

- 1970: 320 acre units for drilling & spacing of J Sand
- 1979: Additional J Sand well allowed per 320 acre unit
- 1980: Section 29 tax credit; Tight gas sand designation (exp. 2002)
- 1983: Codell spaced on 80 acre
- 1984,85: Niobrara added to Codell spacing order
- 1991: J Sand wells can be recompleted to C-N & commingling of all downhole zones allowed
- 1998: Rule 318A allows 5 wells per quarter section in GWA for all Cretaceous age formations (81 townships)(32 acre spacing)
- 2005: Rule 318A modified to allow for section line & quarter section line wells (~ 20 acre spacing 27 townships)

Modified from Wright, 2005 & Weimer, 2005
History & The Various Companies (+/- 40)

- Early (1970s): Amoco and Vessels
- Codell (1981): Energy Oil
- Price collapse mid-1980s
- Price recovery and tight gas sand credits late 1980s
- Late 1980s: Gerrity, Snyder, Martin Exploration, Prima, Basin, HS Resources
- 1991: Amoco farm out Codell to HS Resources and Snyder
- Amoco sells Wattenberg to HS 1997; Patina forms 1996 (consolidation of Snyder and Gerrity properties); Noble acquires Patina in 2005
- Current companies: Anadarko, Noble, PDC, Crestone Peak, Extraction, etc.
Wattenberg Key Ingredients

- Geothermal anomaly
- Basin Center Continuous Accumulation
- Paleostructure -- The Wattenberg High
Continuous Accumulations
(Muddy “J”, Codell, Niobrara)

• Pervasive accumulations that are hydrocarbon saturated
• Not localized by buoyancy
• No down-dip hydrocarbon/water contact
• Updip contact with regional water saturation
• Some water production
• Abnormally pressured (+ or -)
• Production independent of structural closure
• Low φ & K reservoirs
• Sweet spots controlled by fractures & matrix
• Associated with mature source rocks that are either actively generating or have recently ceased generation
• Hydrocarbons of thermal origin
• Fields have diffuse boundaries
• Inverted Petroleum Systems
S = source beds: Skull Creek, Mowry, Graneros, Greenhorn, Carlile, Niobrara, Sharon Springs

Reservoirs = Dakota, Muddy J, Codell, Niobrara
Wattenberg Thermal Anomaly

- Related to igneous masses in basement
- Located where CMB intersects Denver Basin
- Direct temperature measurements in wells
- Ro values
- GORs

Thul and Sonnenberg, 2018
Structure Muddy J Sandstone and Ro
Basic reservoir data, Plainview/Lytle

- Average Porosity: 8-10%
- Average Permeability: 0.1 – 0.2 md
- Connate Water Saturation: 40-50%
- Current Field Size: 800,000 acres
- Pay thickness: 10-30 ft
- Original Reservoir Pressure: 2800 psi
- Depth Range: 7000 to 8,500 ft
- Initial Potentials: 100 to 1,000 Mcf
- Original Spacing: 320
- Current Spacing: 20
- Cumulative Prod: 2,032,436 BO
  87,015,478 MCF
Structure Muddy SS & Dakota Producers
<table>
<thead>
<tr>
<th>Basic reservoir data, Muddy “J” SS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Porosity</strong></td>
</tr>
<tr>
<td><strong>Average Permeability</strong></td>
</tr>
<tr>
<td><strong>Port $r_{35}$</strong></td>
</tr>
<tr>
<td><strong>Connate Water Saturation</strong></td>
</tr>
<tr>
<td><strong>Recoverable Reserves (1970)</strong></td>
</tr>
<tr>
<td><strong>Recoverable Reserves</strong></td>
</tr>
<tr>
<td><strong>Field Size (1970)</strong></td>
</tr>
<tr>
<td><strong>Current Field Size</strong></td>
</tr>
<tr>
<td><strong>Average Pay thickness</strong></td>
</tr>
<tr>
<td><strong>Original Reservoir Pressure</strong></td>
</tr>
<tr>
<td><strong>Depth Range</strong></td>
</tr>
<tr>
<td><strong>Initial Potentials</strong></td>
</tr>
<tr>
<td><strong>Original Spacing</strong></td>
</tr>
<tr>
<td><strong>Current Spacing</strong></td>
</tr>
</tbody>
</table>

Modified from Matuszczak, 1973
Valley Fill Model Muddy (J) Sandstone

A. Wave-dominated deltaic progradation during highstand (Fort Collins Mbr)
B. Drop in sea level; erosional drainages; lowstand
C. Sea level rise; backfilling of valley networks (Horsetooth Mbr; fluvial and marine strata)
Amoco #1 Rocky Mountain Fuel
Sec. 8, T1N-R67W

- Mowry
- Horsetooth Member
- Fort Collins Member
- LSE
- TSE
- LDF
- UDF
Muddy "J" sweet spot (> 500 MMCFG)
Gas symbols for wells cum prod > 500 MMCFG
# Basic Reservoir Data, Codell SS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>7,100 ft</td>
</tr>
<tr>
<td>BHT, °F</td>
<td>260</td>
</tr>
<tr>
<td>Gradient</td>
<td>0.5 – 0.65 psi/ft</td>
</tr>
<tr>
<td>Gross sand, ft</td>
<td>10 to 30</td>
</tr>
<tr>
<td>Net pay, ft</td>
<td>10 to 20</td>
</tr>
<tr>
<td>Porosity, %</td>
<td>6 -12</td>
</tr>
<tr>
<td>Permeability, md</td>
<td>0.05 – 0.005</td>
</tr>
<tr>
<td>Port r_{35}</td>
<td>0.126 μm</td>
</tr>
<tr>
<td>Original spacing</td>
<td>80 acres</td>
</tr>
<tr>
<td>Current spacing</td>
<td>&lt; 20 acres</td>
</tr>
</tbody>
</table>
“More than 80% of the porosity has pore throats smaller than 0.25 μm in diameter” (Pagano, 2006)
Burrows: Teichichnus/Asterosoma, Planolytes
### Basic Reservoir Data, Niobrara

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>6,800 - 7,100 ft</td>
</tr>
<tr>
<td>BHT, °F</td>
<td>260</td>
</tr>
<tr>
<td>Gradient</td>
<td>0.5 – 0.65 psi/ft</td>
</tr>
<tr>
<td>Gross, ft</td>
<td>20-40</td>
</tr>
<tr>
<td>Net pay, ft</td>
<td>20</td>
</tr>
<tr>
<td>Porosity, %</td>
<td>6 -9</td>
</tr>
<tr>
<td>Permeability, md</td>
<td>0.05 – 0.0005</td>
</tr>
<tr>
<td>Original spacing</td>
<td>80 acres</td>
</tr>
<tr>
<td>Current spacing</td>
<td>&lt; 20 acres</td>
</tr>
</tbody>
</table>
Isopach Niobrara
## Basic Reservoir Data: Terry & Hygiene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>4,300 – 4,800 ft</td>
</tr>
<tr>
<td>BHT, °F</td>
<td>120 -160</td>
</tr>
<tr>
<td>Gradient</td>
<td>Normal</td>
</tr>
<tr>
<td>API gravity</td>
<td>40-43°</td>
</tr>
<tr>
<td>Gross, ft</td>
<td>20-25</td>
</tr>
<tr>
<td>Net pay, ft</td>
<td>20</td>
</tr>
<tr>
<td>Porosity, %</td>
<td>13 - 15</td>
</tr>
<tr>
<td>Permeability, md</td>
<td>1.2 – 5.4</td>
</tr>
<tr>
<td>Drive</td>
<td>Solution gas</td>
</tr>
<tr>
<td>Original spacing</td>
<td>80 acres</td>
</tr>
<tr>
<td>Current spacing</td>
<td>&lt; 20 acres</td>
</tr>
</tbody>
</table>
A. Amoco
Rocky Mtn. Fuel D-7
Ne SwSw Sec. 19=T2N-R67W

B. Terry Sandstone

C. Hygiene Sandstone
The “New” Horizontal Play
Another Game Changer

- 8 wells per 320 acres
- Alternating Codell & Niobrara
- Laterals about 335’ apart
- Using tracers & fracture mapping

PDC, 2013

Noble Energy, 2011
Wattenberg Field Horizontal Production

9217 wells
528,824,341 BO
2,838,677,279 MCF
170,117,050 BW
Summary

• Long history of development in a basin center continuous type of play
• GWA = 2.3 BBOE cumulative
• Temperature anomaly, excellent source beds, tight reservoirs
• Wattenberg High paleostructure
• Infill drilling, new horizons, new technology, refracs, changing operators
• Horizontal drilling and multistage fracture stimulation are key drivers
• Wattenberg Field is seeing a new beginning because of the Niobrara & Codell (another 4-5 BBOE)
• New reserves are found in old fields with new technology and ideas!
Wattenberg Field Production
(~40,000 wells)

JSS Discovery
Codell Discovery
Terry/Hygiene Discovery
Niobrara targeted

Amoco sells Wattenberg interests 1997
Amoco Farm Out of Codell to HS Resources and Snyder (1991, 4 yr boom)

Horizontal Drilling
Rule 318A 1998
Rule 318A modified 2005

Cum Prod:
884 MMBO
8.1 TCFG
263 MMBW

BOPD
MCFGPD
BWPD
MCFGPD
Drilling Permit Moratoriums & Fracking Bans

• Drilling Permit Moratoriums
  • Broomfield
  • Erie
  • Superior
  • Lafayette
  • Berthoud
  • Timnath
  • Boulder County
  • Adams County

• Fracking bans
  • Boulder
  • Lafayette
  • Fort Collins